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**Increasing the efficiency of 4-stroke internal combustion engines by prolonged utilisation of expansion, without increase in the density after compression**

Patent Claim : Under the designation "Increasing the efficiency of 4-stroke internal combustion engines by prolonged utilisation of expansion, without increase in the density after compression" I wish to have protected what is stated on pages 2 and 3, in other words what is characterized in that it is written

5 between "My new Principle" and "Patent Claim".

Inventor : Wilm Müller, Urwaldstrasse 22, D -2932 Neuenburg.

Name of this invention : Increasing the efficiency of four-stroke internal combustion engines by prolonged utilisation of expansion without increase in the density after compression.

Description: Conventional internal combustion engines with piston and cylinder do not sufficiently utilize the expansion of the combusted gases, since the power of the gas is far from having been exhausted when bottom dead center is reached and it is released by the opening of the cylinder into the silencer, where generally no further use is extracted from the continued expansion of the gas. It exhausts ["evaporates", "deflagrates", a German pun including the connotation of exhaust] in the truest sense of the word.

Engines are built, but not yet with a sufficiently utilized expansion, since seemingly this would then lead necessarily to an equal degree of "compression over all" and given the high density to excessively high temperature, or alternatively after combustion to excessively high pressure and excessively high temperature.

First of all, a precise explanation of the three important terms used here:

Utilized expansion ratio over all (UERAA) = the ratio of the density of the gas at combustion at top dead center to its density after all its work- (energy) producing expansion. This relationship does not have to be expressed only by the compression ratio = volume (BDC)/volume (TDC); for in a given instance a further expansion can also be utilized by driving a windmill, as for example in the turbocharger.

Degree of charge (DOC) = ratio of the quantity of fresh gas that is actually in the combustion chamber after compression to the quantity of gas that would be in the cylinder at BDC without pre-compression and without pre-expansion.

Compression ratio above all (CRAA) = the ratio of the density of the fresh gas after compression (brought about by compression in the cylinder, possibly with pre-compression and pre-expansion) to its density before this is influenced by the engine. There are limits to this ratio, for other than by this ratio and

5 combustion the material stress through pressure and temperature is only increased by the addition of heat (friction) and reduced by the removal of heat (cooling). At this moment, however, cooling is in fact undesirable, since it lowers the theoretical efficiency.

10 Unfortunately, all conventional engines operate symmetrically, to the extent that their UERAA and CRAA are equal, at least at full throttle. Then one can admittedly obtain the most performance in relation to cylinder capacity [or displacement], but not in relation to fuel consumption.

15 My new principle : One can increase the efficiency of four-stroke internal combustion engines without at the same time increasing the maximum density in the combustion chamber (one can even reduce it, e.g. in order to have less need to cool it), by raising its UERAA as opposed to its CRAA (e.g. by the factor of 1.5 or 2). This principle can be realized in various ways:

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A) Through supplementary devices after the outlet:

Only one half of the turbocharger is used, in that a windmill, although installed in the exhaust duct where in gaining energy it further expands the gas, does not convey the energy thus extracted back to the fresh gas (that would be

25 symmetrical again) but simply uses it for other purposes (e.g. to drive a generator, water pump, fan, air conditioning system, servo-assisted steering and brakes, hydraulics,...), thereby taking some load off the engine. In this way problems of the turbocharger are overcome, such as the fresh gas cooling problem, and there is also no need for an excess pressure safety mechanism  
30 for the cylinder, which mostly simply transforms the excess energy gained through friction in a wastegate valve back into heat again.

B) Equally one can achieve this asymmetry by building the engine with what is admittedly in conventional terms an excessively high compression ratio but which nonetheless admits of a sufficiently large expansion in the cylinder itself; however one can avoid an undesirably high maximum compression which would then occur after compression by lowering the maximum degree of charge (at full throttle and low revs) accordingly below 1, so that once again the desired maximum compression is achieved. Since the degree of charge is derived from the rate of charge and its duration, it can be reduced in three different ways:

- 10 a) By pre-expanding the gas by means of a flow resistance or a windmill. Conventional carburetor motors and gas motors already expand the fresh gas according to load via the throttle flap; however at full revs they permit the gas to flow with the least possible hindrance. All that is new is that one restricts the flow even at full throttle. Then one can also control the partial load by increasing this restriction. In a windmill with no friction this would correspond to the amount of energy drawn from it.

The solution with the windmill is to be preferred to that with the resistance, since it yields additional energy, instead of pre-heating the fresh gas and so putting unnecessary load on the engine.

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- b) By controlling the inlet in such a way that it is closed again even before BDC is reached. In a Wankel engine this means that the inlet slit is moved closer to the outlet slit so that its piston edge already closes the inlet of the induction chamber before BDC (the moment of maximum volume in this chamber). A particularly clever approach would be to control the load even straightaway by a greater or lesser degree of advance closing of the inlet. With a Wankel engine this could be readily achieved by a slider parallel with the cylinder wall that could widen or narrow the slit even during operation, in the direction of rotation of the piston.

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- c) But even after passing BDC one can still reduce the degree of charge by simply leaving the inlet open "too long", so that the excess fresh gas flows right back into the inlet channel. For the Wankel engine this means that the inlet slit

is broadened so far in the direction of rotation of the piston that its edge only closes it again as late as desired after BDC. Again, one could control the load with a slide-operated closer edge over the full width of the slit.

- In this approach, the returning fresh gas scarcely poses a problem, since even
- 5 in a normal four-stroke engine at any time there is one cylinder in the induction stroke which can easily accept the gas escaping from the other cylinder.
- Equally, even with the one-cylinder Wankel engine, there is always one of the three chambers engaged in drawing in fresh gas (still more so in the case of the two-cylinder engine).